Bolt Beranek and Newman Inc.

LEVEL II

Report No. 4124

Command and Control Related Computer Technology: Packet Radio

Quarterly Progress Report No. 16
1 September to 30 November 1978

May 1979

Prepared for:
Defense Advanced Research Projects Agency

BBN Report No. 4124 May 1979

COMMAND AND CONTROL RELATED COMPUTER TECHNOLOGY:
Packet Radio

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This research was supported by the Defense Advanced Research Projects Agency under ARPA Order No. 2935 Contract No. MDA903-75-C-0180.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER: BBN [redacted] -4124

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

6

4. TITLE (and Subtitle): COMMAND AND CONTROL RELATED COMPUTER TECHNOLOGY: PACKET RADIO.

9

5. TYPE OF REPORT & PERIOD COVERED: Quarterly Progress rept. no. 16, [redacted] 1Sep[redacted]-30Nov78,

6. PERFORMING ORG. REPORT NUMBER:

10

7. AUTHOR(s): M. Beeler, J. Burchfiel, R. Perlman, W.W. Plummer, V. Strazisar, [redacted]

15

8. CONTRACT OR GRANT NUMBER(s): MDA903-75-C-0180, ARPA-Order-2935

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Bolt Beranek and Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:

11. CONTROLLING OFFICE NAME AND ADDRESS:
Advanced Research Projects Agency
Information Processing Techniques Office
1400 Wilson Blvd., Arlington VA 22209

11

12. REPORT DATE: May [redacted]79

13. NUMBER OF PAGES: i + 18

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

12 22p.

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this document is unlimited. It may be released to the Clearinghous; Department of Commerce for sale to the general public.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This research was supported by the Defense Advanced Research Projects Agency under ARPA Order No. 2935.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

packet radio, computer communications, PDP-11, TCP, gateway

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document describes progress on development of a packet radio network. Activities reported include work on Station Software and Internetworking Research and Development.

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1. INTRODUCTION

An important component of the Packet Radio project is the station software, providing a variety of control, coordination and monitoring functions. BBN's role in developing this software is to specify, design, implement and deliver programs which perform these functions.

During this quarter continued progress was made both in design areas and in preparation for the major implementation task of modifying the Labeler process for Channel Access Protocol (CAP) version 5. This involves negotiation of protocol details with co-contractors. Section 2 below covers these efforts.

Section 3 of this report covers work during this quarter on station software itself, followed by progress in internet areas described in Section 4. Of particular interest here is the availability of the new TCP, version 2.5.1, as well as further gateway development and testing.

Section 5 deals with hardware; the major event in this area during this quarter has been the installation and initial powering up of two radio PR units at BBN.

2. MEETINGS, TRIPS, PUBLICATIONS

2.1. Meetings and Trips

2.1.1. PRWG meeting

BBN personnel attended the Packet Radio Working Group meeting this quarter, held September 27-29, at Collins Radio in Texas. Of principal concern to our efforts was discussion of a down-line load service for Packet Radio units. This and subsequent discussions arrived at the conclusion that the station is a logical place for this service, and initial planning of its design was begun. This facility will receive load requests from unloaded PRs, forwarded to the station by the network of operating PRs. The load process will then send a sequence of packets to each PR requesting a load, thus enabling the PR to begin execution of Channel Access Protocol and enter the network as an operational node.

Also at the PRWG meeting there arose further support for the separation of the station tasks and the internet gateway tasks. Discussion of our efforts in minigateway development appears in previous reports (especially see QPR 14, pages 43-48).

Probably the most immediately vital outcome of the PRWG meeting was resolution of several Local ROP (LROP) design issues. This was achieved through discussions we led and guided by our PRTN 259 (see section 2.2). It was decided that:

- The LROP contains station ID, labeled/unlabeled flag, load request flag and sequence number, and PR type (EPR/IPR).
- Periodic LROPs will have the highest priority of all packets. This is to assure the validity of link quality measurements.
- PDPs contain the link quality at each data rate.
- Dummy traffic exists at each data rate, if needed.
- PDPs are not always sent with open/close SPP functions asserted.

- PDPs contain raw transmit counts at each data rate; the station may in the future use this to avoid congestion.

And finally, UCLA made a request at the meeting for a measurement file entry to announce the correspondence between a TIU and its attached PR's IDs. (See section 3.1.2.)

2.1.2. SATNET meeting

We hosted a meeting with SATNET representatives November 6 to determine the configuration of gateways and port expanders at SATNET sites. The main issue is ARPA's desire to have an operational SATNET by January 1, in preparation for use of SATNET connections to Europe when the ARPANET connection to London is removed in June of 1979. The current plan is to use the SIMPs to provide a virtual "IMP-IMP long distance telephone line" between the United States and England. An implication of this is that the operational gateways will not be available for debugging. Because of ARPA's strong concern for a continued environment for internet development, the plan arrived at has two gateways at each SATNET site. The present PDP-11/34 gateways will continue to be used for development, while new LSI-11 minigateways will be installed as the operational gateways. These minigateways will include port expanders for the ARPANET and for the SATNET, ports of which will serve the PDP-11/34s. A copy of the resulting configurations and a list of hardware was presented to ARPA. The cost of the new hardware required, however, is a significant concern and throws serious doubt on this approach as a means for SATNET operation. The cost appears to exceed $300K.

In order to support the SATNET port expander, modification of the Host/SIMP protocol is planned. Presently, replies from the SIMP carry only host reference numbers, which the host matches to the corresponding request. The goal is to support two different machines attached to the SATNET port expander, each

running a copy of Host/SIMP, with only one physical connection to the SIMP. The main change is that every message will carry an address.

2.1.3. Internet and access control meetings

At the Internet meeting held at SRI in October, Virginia Strazisar presented our ideas on congestion control in the catenet. We are in the process of implementing an alternate routing scheme in the gateways as outlined in IEN #30. In this design, gateways exchange information with each other regarding the up/down status of their network interfaces and their connectivity to gateways on the same networks. This information is used to determine shortest length routes to each network in the catenet. One method of alleviating congestion which was outlined in IEN #30 is to load split traffic on all routes of equal length. We are currently implementing this mechanism as part of the modifications to support alternate routing. Although load splitting can aid in controlling congestion, ultimately the packet sources must be quenched to prevent overloading the entire catenet. Gateways currently drop packets which they cannot forward due to congestion; a simple extension of this mechanism is to notify the source, identified by the packet's internet source address, that its packets are being dropped. The internet source can then quench its flow of traffic into the catenet in order to prevent further packet loss. Over a period of time, the source can again increase its traffic flow into the catenet, backing off when source quench messages are received from the gateway.

Our presentation was not intended as a complete design for congestion control as several questions remain to be answered. In particular, if several sources are sending traffic into one congested gateway, can all the sources be treated fairly? and,

can a gateway detect and report congestion before packets are lost? We plan to continue work on the design of mechanisms to control congestion and propose to implement these as an addition to the gateway alternate routing scheme currently being implemented.

When access control was discussed at Internet meetings, it was usually treated as a local problem, in which gateways would accept or reject an arriving packet. We noted that it is a global problem, since the internet has to route a packet over a legal route if one exists. Otherwise a packet would be dropped because gateways tried to send it via a gateway that would reject it. People proposed fixes to this problem in which a packet, rather than being dropped, would be turned back on its path until it reached a gateway that had an alternate path to send it on. We rejected this idea as impractical, both because of the amount of history that would have to be kept either in the packet or in gateways to remember where the packet has been, and because of the inefficiency of groping ones way through the internet. We wrote up our approach to solving the problem of access control in IEN #58, "Access Control -- An Informal Discussion" and presented the ideas at the Internet meeting in October. At the meeting it was decided that discussion of the topic should continue and a small meeting was scheduled for November at ARPA. At the ARPA meeting, ARPA explained the current practical reasons for the necessity of access control, and introduced a new facet of the topic that needed to be designed, namely spoof protection. We discussed several approaches to spoof protection.

2.1.4. Meetings with Prof. Gallager

We invited Professor Gallager from MIT to talk to us about his latest work in routing, especially as related to our project. We decided that it would be beneficial to both groups to keep up

informal contact for exchange of ideas. Prof. Gallager invited us to occasionally attend the informal seminar held by his group at MIT each week. At the occasional seminars we attended, we listened to their latest research directions, filled them in about our current state, and suggested problems that they could work on that would be of direct benefit to us such as congestion control, alternate routing strategies, intersubnet route setup in a multistation environment, and algorithms for dynamic selection of stations in a multistation environment in which PRs and stations could change identity. We expect this informal relationship to continue.

2.1.5. Meeting with McQuillan's group

During this quarter we participated in an informative meeting with John McQuillan's ARPANET group, also of BBN. John discussed ARPANET routing and recent results on performance and routing design (for which see BBN Report No. 3803). In turn, we explained the general principles of the PR net and routing therein. Although the routing problems each group must solve are vaguely similar, a major difference is apparent in that the shared broadcast channel of the PR net approximately constitutes a fully connected net, only some arbitrary portion of whose links are up at any given time. The ARPANET, in contrast, is sparsely connected, by links which are usually up. An aspect of ARPANET research which seems more applicable to PR net efforts than routing design is, is study of traffic level variation with time. Essentially all measures of traffic volume in the ARPANET were found to be extremely noisy. This places grave doubt on the applicability of routing methods such as that of MIT's Prof. Gallager, which adjusts to the marginal delay (derivative of traffic delay with respect to amount of traffic). Unfortunately, we have no reason to expect traffic level (or delay) variation in

the PR net to be any more smoothly behaved than it is in the ARPANET.

2.1.6. TCP meeting

BBN personnel participated in discussions at the TCP meeting, held September 18-19 at SRI. Resolutions from that meeting are not bearing on Packet Radio work strongly and are reported in the Internet Experimenters Notes, and so will be omitted here.

2.2. Publications

PRTN 258, "Remaining Issues in Stationless Compatible Routing"

This PRTN discusses points in the design in which choices of implementations are possible, discusses the tradeoffs between the choices, and makes recommendations about which choice should be implemented.

PRTN 259, "Thoughts Involving LROP Things"

The acronym of this PRTN, TILT, brings to mind the cheat detection of pinball machines in amusement arcades. The association is intentional. In digital synthesis of music and speech sounds, the computer community grew to understand and quantify the amount of precision needed to reproduce a sound to a given degree of faithfulness. Similarly, the author sees the networking community (and the PRWG in particular) placing faith in a mechanism (Local Repeater On Packets, to measure link quality) before fully understanding the sampling rate needed to secure a meaningful measurement. This PRTN examines some of the consequences of fluctuation in link quality measure to be expected on purely statistical grounds. It also presents some elementary assessments of how often various amounts of fluctuation should occur. Although presented at the PRWG meeting

this quarter, this PRTN and the issues it raises were not discussed in depth.

PRTN 260, "Specification of a Rudimentary Multistation Capability"

This PRTN presents a specification of a design to meet the Packet Radio project's need of robustness. The multistation capability is termed "rudimentary" because it makes the simplifying assumption that all PRs are labeled by all stations, and thus, although it meets the immediate needs for the PR net, does not answer the future need of network expansion that a complete multistation capability would provide.

PRTN 261, "Resolution of LROP, etc. Issues"

At the September 27-29 PRWG meeting, many of the LROP, neighbor table and PDP design issues identified in PRTN 255 (see our QPRs 14 and 15) were agreed upon. To provide a clear and complete documentation of these, PRTN 261 was written. This document serves as a specification for these aspects of CAP 5, the principal changes from CAP 4. One item of remaining concern is whether the neighbor table will be able to store all the neighbors. This concern, principally voiced by BBN, is discussed in PRTN 261, and implementation alternatives are presented. It will be interesting and informative to follow the performance of the neighbor table mechanism in the months to come, to see whether this concern is justified.

Internet Experimenters Note 58, "Access Control -- An Informal Discussion"

This publication was distributed to the internet group in conjunction with the October meeting. See section 2.1.3 for further details.

2.3. Negotiations and Informal Documents

2.3.1. LROP, etc. design

An important aspect of our contribution to the design and specification aspects of the multi-contractor Packet Radio project is the informal negotiation and documentation of issues with our fellow contractors. This quarter saw significant informal contact regarding LROP, neighbor table, and PDP design. The PRWG meeting reported in section 2.1 was followed by additional discussion, principally with Collins personnel implementing these features of CAP5 in the PRs. Their concern was mainly to minimize the amount of code required, so that CAP5 would be sure to fit in the EPRs. This resulted in the publication of PRTN 261 (described in section 2.2).

2.3.2. 1822 resolutions

Also this quarter we distributed to Collins Radio and SRI, at their request, additional copies of the note on resolutions of 1822 interface issues reached at the June 19-21 PRWG meeting (see QPR 15). Additional discussion of these issues arose at the September 27-29 meeting this quarter, mainly resulting in agreements that Collins would revise the way their PR software used their 1822 hardware, in order to more closely conform to the prior resolutions.

2.3.3. Route suppression bit

Another informal negotiation topic this quarter has been the route suppression (RSUP) bit in the packet header. When the station forwards a packet, it ordinarily also attempts to find and assign a point-to-point route for further such traffic to use. If the RSUP bit is set, this route finding and assignment action will be suppressed. The RSUP bit may be set either by a PR, or by an attached device (e.g., TIU), in which case its

setting is preserved by the PR. The concept of the RSUP bit is presented in greater detail on pages 9 and 11 of our QPR 15. During this quarter, our proposal was accepted and we negotiated with Collins personnel to clarify the proper implementation of the bit in the PR.

2.3.4. Station bibliography

During this quarter we prepared a brief bibliography of current documentation explaining the details of station software, its operation, programming, etc. This bibliography is as follows:

Packet Radio Network Station notebook -- primary reference; contains various PRTNs; "Operating the Packet Radio Network Station" is a chapter therein and constitutes a user guide for the station operator.

PRTN 174 revision 6, "Packet Radio Network Station Labeling Process" -- describes the latest version of the labeler, thus superseding the copy of PRTN 174 now in the Station notebook.

PRTN 212 revision 5, "Specification of Measurement File Entries" -- describes the latest format and contents of such entries, thus superseding the copy of PRTN 212 in the Station notebook.

PRTN 141, "Cross-Network Debugger User's Manual", and
BBN Report 3377, "XNET, Cross-Network Debugger for TENEX, User's Manual" (which is an update of PRTN 141), and
[BBNA]<ELF>XNETUPDATE.DOC on-line computer file
-- these describe the use of XNET to load, debug, monitor, remotely control, and interact with the station. Use of the disk for storing software is also covered. This manual is ordinarily distributed with the Station notebook.

PRTN 125, "Functions and Structure of a Packet Radio Station" -- PRTN version of 1975 NCC paper. Describes initial design of station. Good background material.

PRTN 216, "Specification for an ELF System with Disk and Net Loading Facilities" -- covers major extensions made to ELF specifically to support PRN needs. Reference for ELF operating system itself is "ELF System Programmer's Guide", available on-line but written at SCRL, not BBN.

Also, certain BBN PRTNs bearing on SPP and CAP are relevant, although these are not peculiar to the station. These are:
PRTN 177, "SPP Definition",
PRTN 194, "Point-to-Point Routing Proposal", and
PRTN 239, "Use of IDs in Routes".

3. THE PACKET RADIO NETWORK

3.1. Station Programming and Testing

3.1.1. ELF system

We released a new ELF and connection process to support more connections for measurement runs. In particular, there is no XRAY process in this configuration; the connection process uses that space for increased storage.

The gateway has been modified to interpret both version 2.5 and version 4 internet headers. In interpreting version 4 internet headers, the gateway checks the packet length field, checks and decrements the time to live field, and verifies the internet header ones-complement checksum. The gateway does not yet support fragmentation.

3.1.2. Labeler

Several small improvements to the CAP4.9 Labeler were made during this quarter.

1) The Labeler dialogue was enhanced to include a no change option for the yes/no questions pertaining to the running of the Labeling process.
2) Some source files for the Labeler, which had been destroyed during a period of severe disk problems in late August, were recreated through older sources and editing notes.
3) A new Labeler was delivered to SRI incorporating the TIU ID - PR ID measurement entry requested by SRI and the carriage-return default for parameter setting in the Labeler. Also included in the delivery were: PRTN 212 revision 6 describing the new measurement entry, an updated labeler chapter of the station operator's guide, and an updated version of PRDATA which handles the new measurement entry.

The major effort was directed toward the CAP5 labeler, in both design and code generation. Portions of the Labeler pertaining to the assignment and use of good neighbors were removed, and the resulting Labeler tested.

The connection handling was redesigned to handle both SPP and non-SPP connections with the same routines. This proved useful in the subsequent implementation of the listening connection; this third type is an SPP connection initiated by the Packet Radio Units to send PDPs. The design was implemented and then tested through mock SPP packets generated by XRAY.

3.2. Support

SRI asked about the XNET debugger sending (internet) packets which are too large for a PR net to transport in its packets. In response, we prepared a version of XNET which knows about the packet size limitation of PR nets and reduces its packets accordingly. Such an XNET debugger may be used by SRI to debug TIUs, for example.

4. INTERNETWORKING

4.1. Transmission Control Program (TCP)

Code aimed at repairing all reported TCP bugs has been included in the TCP sources for TENEX and TOPS20. After some period of negotiation, a 2020 became available for monitor debugging at Digital Equipment Corporation in Marlboro, Massachusetts. This machine is now being used two afternoons each week for TCP activities.

On 21 November 1978 TCP version 2.5.1 was installed for experimental testing by members of the Packet Radio group. Somewhat after this the group at UCL produced a program which could cause a monitor crash. Upon investigation the cause was traced to a questionable definition of a "standard" macro which is intended to decrement a structure field. The standard definition did not consider the carries produced by decrementing a 0 and thus modified the field to the left. The reason this showed up only in the UCL program is that it is the first program which had TCP buffers in page 0 of its address space. It was the "current buffer page" field which was being initialized using the DECR macro. The problem was repaired.

The first version 4 TCP was produced by editing the current version 2.5.2 files, changing structure definitions and algorithms as needed. Thus 4.0.0 performance and capabilities are identical to version 2.5.2.

4.2. Gateways

In order to verify the performance of version 4 (Internet Protocol) gateways, a program call GWTEST (Gateway test) was constructed. Basically it started as a previous incarnation (SIQTST) and was modified to handle version 4 of IP.

Testing of version 4 hosts may be done using a testing gateway program. This program functions as a gateway from the ARPANET to the ARPANET and may be run on any TENEX or TOPS20 machine. This gateway is purposely designed to accentuate real world shortcomings which will be encountered. For instance, the testing gateway introduces errors, some of which are undetectable, delays, drops and reorders packets. In certain special cases such as TCP packets which have the SYN control bit set, the probabilities are different so as to provide more of a "worst case" communications medium simulation.

During this quarter we were asked for clarification of the solution to the i/o blocking problem between the Host/SIMP protocol module and the Reliable Transmission Protocol (RTP) code in gateways on the SATNET. (See QPR 14, top of page 43 for further background.) The motivation for the solution we chose is as follows. Both the RTP code and Host/SIMP each have a limited number of buffers for communicating with each other. All of RTP's buffers may happen to be waiting for write operations to Host/SIMP to complete. We cannot allow all of Host/SIMP's buffers to be writing to RTP, since that can lead to the deadlock described in QPR 14. Thus at least one Host/SIMP buffer should be used to read from RTP. If that buffer is then filled with a packet which turns out to be unacceptable at this moment (such as if it were destined for writing to RTP, thus threatening a deadlock), the packet must be discarded ("refused"). To refuse the packet Host/SIMP must (per protocol specification) send the SIMP, via RTP, a message saying that this packet, identified by "host reference number", was refused. To send this refusal message it must exist in a packet buffer, but there are no packet buffers available. (The buffer freed by dropping the refused packet just received from RTP must be re-used to maintain a read outstanding from RTP.) Thus we are in a very difficult

situation. To avoid deadlock we must keep a read outstanding, and to do this we must be capable of (occasionally, we hope) dropping packets, and to do that we must send packets for which we have no buffers. Our solution is to say that this condition is one we expect to be transitory, and that a short list can be kept of host reference numbers for which Host/SIMP should send refusal notifications when the condition eases. If this condition is not transient, that is, if it persists so long that the several slots on the list are insufficient, then this is presumably symptomatic of a major foul-up in communications, and issuing a "restart request" to clear the situation is appropriate.

Debugging of the Host/SIMP protocol module of the gateway in conjuction with actual SIMPs was begun. Joint debugging uncovered bugs in the Host/SIMP module of the gateway that did not arise in loop-back mode. The main bug was associated with packets being byte-swapped (since in loop-back mode, the packets would be doubly byte-swapped and therefore seen as correct). Also, a modification was made to the restart logic in the protocol, and we were initially not compatible with the SIMP, which was implemented after the protocol change was made. Other bugs occurred because the core gateway had undergone modifications in the months between loop-back debugging of the Host/SIMP module and joint debugging with the SIMP, so that the Host/SIMP module was no longer compatible with the core gateway. These bugs were all dealt with, but it was decided that release of all the software would wait until streams were implemented in the SIMPs and could be tested with the gateway.

5. HARDWARE

5.1. Boston Area PR Network

At the close of the last quarter, we were almost ready to install the two PRs at BBN. These will be useful for three reasons:

1) The new PRs will be identical to those in operation at SRI and Collins. They will not require software patches to use a second 1822 interface, normally connected to the radio unit, to simulate radio connectivity, as the PRDUs (Packet Radio Digital Units) we have been using do. Also, the PRs will be capable of executing the CAP 5 code, which will depend on a new PROM operating system not present in the PRDUs.
2) The radio link will permit more realistic testing and debugging, since it may occasionally drop (and hence cause duplication of) packets. The PRDU digital link is error-free, so problems arising from imperfect link performance could not be addressed in the BBN test bed.
3) The two PRs will constitute the beginnings of a Boston area PR network. As PRs are added in the future, users at MIT and Lincoln Labs will have the opportunity to experiment and utilize the net. Also, our station testing and debugging activities will become increasingly realistic as the size of the Boston net increases. Problems of scale will appear here, where they are more quickly identified and remedied, instead of at SRI.

The one remaining piece of hardware necessary for installation of the PRs was 1822 interface cable. This arrived early this quarter and was installed, connecting the PR on the seventh floor to a PDP-11 in the North Bay computer room on the first floor.

We requested and received final permission from ARPA to generate RF radiation in the Boston area by operating the PRs. We then invited Collins personnel to visit our facilities for a final check prior to powering up the PRs. This visit occurred November 16-17.

Unfortunately, a lack of familiarity with PRs on the part of our technicians assembling them, together with a lack of documentation regarding a particular detail, resulted in improper assembly. The connector for the maintenance monitor, which is not clearly labeled and is not keyed, was installed upside down in both PRs. This, we hypothesize, caused one or more power supply voltages to take back paths through the maintenance monitor circuits and return to the main PR circuits, where they were applied to sensitive RF components. The result was a burn-out of parts of each PR, causing total inoperability.

We shipped both PRs back to Collins for repair. Since then, measures have been taken to make the proper installation of the maintenance monitor connector clearer. Unfortunately, this setback may adversely affect our delivery of station software compatible with CAP 4.8, since we have no on-site debugging facilities. (The PRDUs cannot run CAP 4.8 due to PROM operating system changes.) We plan to use SRI facilities remotely as much as possible to minimize this impact.

5.2. Miscellaneous Hardware Work

The only additional hardware efforts this quarter were treatment of a failed microcode ROM in station PDP-11 number 2, and some intermittent problems with station PDP-11 number 1. A service call from DEC cured the former, while some work by our technicians fixed the latter.